MSR upgrade for clinical MEG

A. Pasquarelli[1], S.N. Erné[1], and A. Trebeschi[2]

[1]*Department of Bioelectromagnetism, ZIBMT, Ulm University, D-89069 Ulm, Germany*
[2]*Advanced Technologies Biomagnetics, Pescara, Italy*

1 Introduction

To accommodate the new Argos 500 MEG instrument [1] a general upgrade of the existing 2+1-layer magnetically shielded room at the neurological department was necessary.

Due to the innovative technology and the ambitious goal more stringent requirements where set for shielding performances and shielding anisotropy.

The upgrade process of the existing MSR was carried out in cooperation with Advanced Technologies Biomagnetics and consisted in:

1. Adding a third layer of soft magnetic material.
2. Redesigning the structure supporting the magnetic layers of the door to improve the matching with the walls to reduce the door effects.
3. Redesigning completely the operation of the door by removing all hidden mechanisms and leverages and replacing them with external pneumatic locks.
4. Adding extra features like automatic emergency release of the door in case of power and or air-pressure failure and manual locks disengage in case of mechanical failure.

2 Methods

The Magnetically Shielded Room (MSR) available at the Neurology department of the Ulm University, served since 1988 for the shielding needs of the previous MEG system (14 + 14 Channels) by Dornier.

That system was based on wire wound gradiometers and performed a very large dynamic range thanks to the special feature of the CTF SQUID read-out system.

The old system was employed in research activities mainly focused on neurophysiological studies.

Argos 500 is the new all-magnetometer-based vector-MEG system, which is not only going to replace the older one, but is also targeted to an intensive patient throughput rate in clinical diagnostics and research.

This is therefore not only a major technology upgrade, but also a significant change in the strategy of use, which is only possible if the clinical criteria for patient handling and the technical criteria for system management are fulfilled.

Of course the first concern which rises when changing from gradiometers to magnetometers is the noise level inside the MSR.

A series of measurements was then performed to check the environmental noise field, the actual shielding performances of the existing MSR and to compare this new data with the older ones measured when the MSR was built, in order to determine if some kind of degradation did happen over the years of use.

Despite the location inside an hospital the environmental noise measurements showed moderate intensity levels both at daytime and in the night, reaching values of 100 pT/√Hz @ 1 Hz during the heaviest daytime hours.

On the other hand, average shielding values of 82 @ 0.015 Hz and 158 @ 0.1 Hz were measured, showing that the room performances did not change since the assembly in 1988 confirming the reputation of MSR's as long lasting maintenance-free facilities.

Also it was confirmed an already known weakness exhibited in the door area, where relevant inhomogeneities in the residual field were detected, accompanied by 20% loss of performances in the axial direction with respect to the transverse direction, quite large for a room with a square form.

Considering the combination of environmental noise and shielding performances and making a comparison with similar facilities in Ulm [3, 4] and in Chieti [5], where other magnetometer-based system have been operated since 1997, we came to the conclusion that an improvement in the performances was desirable in order to allow a reliable operation of the magnetometers.

We decided to add an additional layer of soft magnetic material. Two possibilities were available:

1. Outside the MSR with the advantage of leaving the inner room unchanged, but with the major drawbacks of a large amount of material

required not only for shielding but also for the frame structure and the very complex assembly procedure needed to disassemble and reassemble the MSR

2. Inside the MSR, thus reducing the available room for operations, but allowing lower costs due to an easier assembly and the lower amount of material required.

Considering that Argos 500 is a gantryless system with limited room requirements both for operation and maintenance (including helium refilling), we determined that the dimensions of 3 m x 3 m could allow the assembly of the additional layer inside the MSR, although with a moderate spacing from the adjacent layer.

Before taking the final decision we performed an estimation, using a mathematical model based on the Kaden's formulas [2], of the possible increase in shielding which could be obtained under different configurations.

The model employed in this simulation was previously successfully used in predicting the performances of the MSR's in the other facilities mentioned above.

We simulated the additional layer placed outside and inside, running the calculations for different layer spacing.

We found a good compromise in a configuration with the additional layer assembled in the inside at a gap of 50 mm, thus leaving 2.9 m x 2.9 m for operations, which predicted an improvement in shielding by a factor of 2, thus reaching about 300 @ 0.1 Hz.

The second important issue was the improvement of the door magnetic behavior, in order to reduce the field inhomogeneities.

After an accurate investigation we found that the poor mating between door and wall was responsible for the lack in performances. We designed therefore a different mating technique to insure the best possible magnetic contact.

Last but not least we made considerations about safety standards in dealing with patients and found that a failure of the locking system of the door could lead to a difficult situation, because no auxiliary disengagement was available.

We decided therefore to remove from the door all hidden mechanisms and leverages, replacing them with external pneumatic locks and to add extra safety features like an automatic emergency release of the door in case of power and or air-pressure failure and a manual locks disengage in case of mechanical failure.

3 Construction

To simplify the assembly procedure and to avoid an overload of the available structures and supporting elements, we designed a lightweight yet reliable frame for the layer to be added.

Also the design of the panels of magnetic shielding material was done with the aim of facilitate the construction and in fact we found convenient sizes and shapes to allow the construction of all the sides of the room using modules with two form factors only, plus six corners. The only exceptions were given by the plates placed at peculiar positions like ventilation, projector holes, anchoring points, electrical feedtroughs.

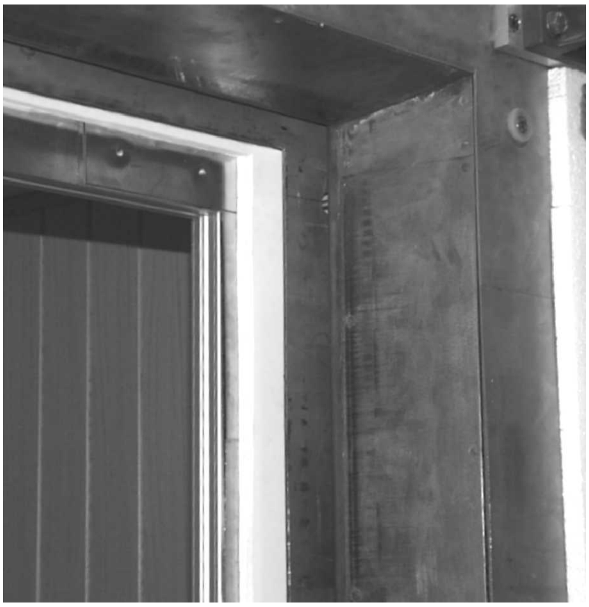

Figure 1**:** *Upper corner of the door counterframe. Overlap areas of the three layers are clearly visible*

To fit the architecture of our new instrumentation we abandoned the anchoring in the ceiling used by the old suspended gantry and provided new anchoring points for bed and dewar in the floor. The floor itself was realized by means of a 3 cm thick plywood plates assembly and was suspended over a proper clearance structure, to avoid stress and reduce the transmission of vibration to the magnetic layers to a minimum.

New contact elements were added to achieve a good magnetic mating between the door and the front wall, especially at the floor side where the two counterparts of the inner layer did not overlap, leaving a gap of a few millimeters instead.

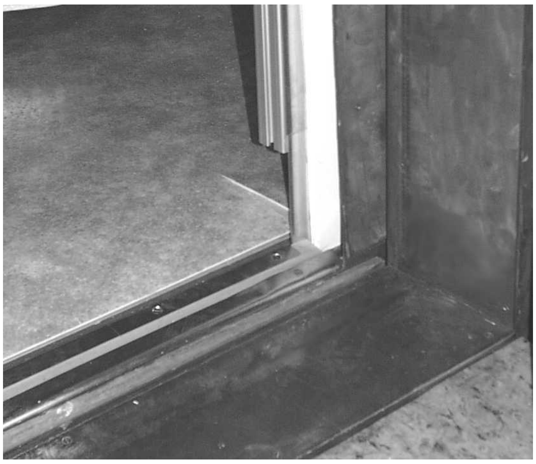

Figure 2**:** *New profiles improve the magnetic contact of the second and third layers with the corresponding door elements.*

The third layer of the door was built on a sub-frame provided with adjusting screws, in order to get the best possible magnetic contact, but without stressing the panels.

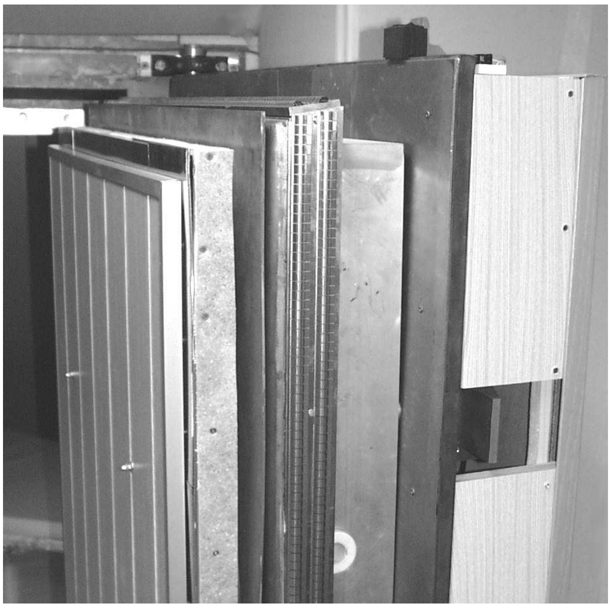

Figure 3**:** *Three-layers door structure. The third layer is on an adjustable sub-frame.*

The door was provided with a pneumatic locking system, with the added feature of an extra air-pressure reservoir and a manual disengage to allow the opening maneuver also in case of electric power loss.

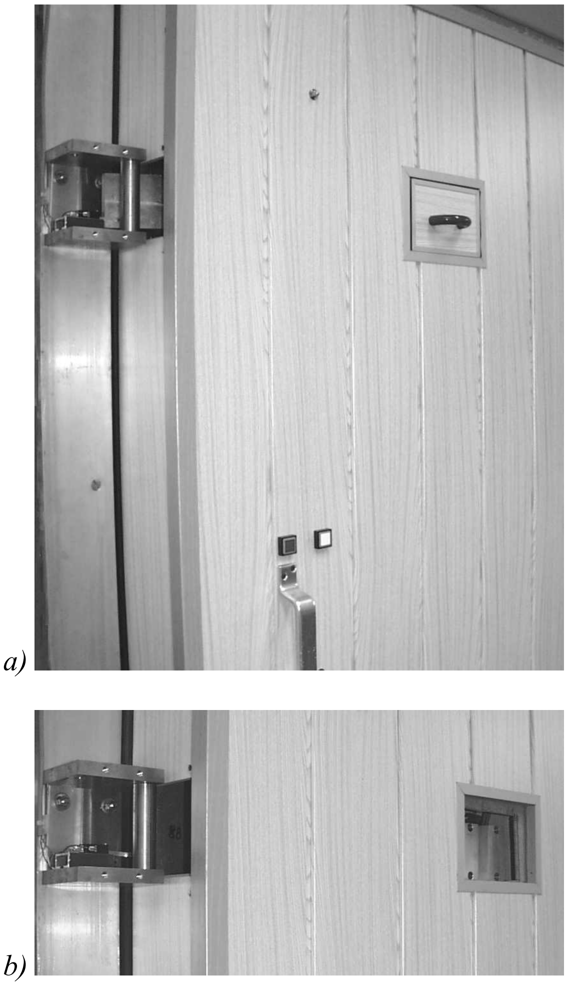

Figure 4**:** *a) Door locked during normal operation,. b)The manual disengage frees the door.*

General safety was also improved under many smaller details including a larger tube for helium venting able to sustain the gas flow also in case of thermal leak in the dewar and a sensor system to control helium flow rate, air ventilation and air quality, to raise an alarm if the air properties reach dangerous values.

4 Results

After the work was done we came back to measure the new performances and found a good agreement with the values predicted by our simulation. The measured results are summarized in Table1.
Another good result was observed in the improved homogeneity of the residual field which now presents a spread among different axes dropped of only 6%, yielding a much better field homogeneity which is very useful in systems with software gradiometers.

Table 1: *Shielding values before and after the assembly of the third magnetic layer.*

2 Layers		
Freq. (Hz)	*Shield*	*Shield (dB)*
Measurement on X (longitudinal axis)		
0,1	153	43,7
0,015	74	37,4
Measurement on Y (transversal axis)		
0,1	165	44,3
0,015	90	39,1
3 Layers		
Freq. (Hz)	*Shield*	*Shield (dB)*
Measurement on X (longitudinal axis)		
0,1	301	49,6
0,015	158	44,0
Measurement on Y (transversal axis)		
0,1	310	49,8
0,015	168	44,5

5 Discussion

In order to avoid a large reduction of the space available in the inner room, the gap between the second and the third layer was limited to 50 mm. The disadvantage of this restrain was a reduction in the effectiveness of the additional layer, when compared with the expected performances of a layer placed at a more typical gap of 150 to 180 mm. Nevertheless the overall performances of the MSR are now comparable with the past results in large rooms in Ulm and in Chieti.

The added safety features allow a future operation in the clinical environment since now they meet our standard requirements.

References

1. A. Pasquarelli, R. Rossi, P. Bucciarelli, V. Fantacone, M. Ziolkowsky, and S.N. Erne’, “Argos 500: a whole-head vector-MEG”, *this volume.*
2. H. Kaden, *Wirbelstroeme und Schirmung in der Nachrichtentechnik*. Berlin. Springer 1959
3. S.N. Ernè, A. Pasquarelli, H. Kammrath, S. Della Penna, K. Torquati, V. Pizzella, R. Rossi, C. Granata, M. Russo, “Argos 55 - The New MCG System in ULM”, in *Recent Advances in Biomagnetism*, T. Yoshimoto, M. Kotani, S. Kuriki, H. Karibe, and N. Nakasato, Eds. Sendai: Tohoku University Press, 1999, pp. 27-30.
4. A. Pasquarelli, H. Kammrath, U. Tenner and S.N. Erné, “The New Ulm Magnetic Shielded Room”, in *Recent Advances in Biomagnetism*, T. Yoshimoto, M. Kotani, S. Kuriki, H. Karibe, and N. Nakasato, Eds. Sendai: Tohoku University Press, 1999, pp. 55-58.
5. V. Pizzella, S. Della Penna, S.N. Erné, C. Granata, A. Pasquarelli, K. Torquati, R. Rossi, and M. Russo, “A 165-channel neuromagnetometer for multimodal A 165-channel neuromagnetometer for multimodal imaging ”, *this volume.*